A NOVEL TECHNIQUE TO MEASURE SMALL CALIBER PROJECTILE BALLOTING

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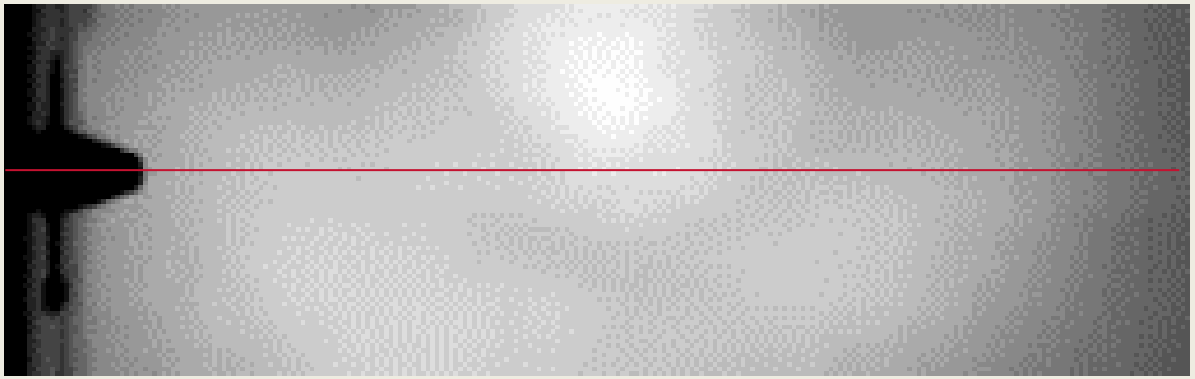
Balloting

- **Dynamic misalignment of the projectile within the barrel of a gun**
- **In-bore yaw is the static misalignment of the projectile**
  - **i.e. the offset angle stays constant and rotates with the rifling**
- **Symptoms of balloting include**
  - **Increases in dispersion immediately from muzzle exit**
  - **Increased gun tube wear**

5.56mm Short Gun



McCoy, R.L. “Modern Exterior Ballistics Second Edition,” Atglen, PA. Schiffer. 2012

Explanations

- **Balloting can occur because of the projectile entering the bore misaligned**
  - **Run out in the case neck**
  - **Non-axisymmetric projectiles**
  - **Unsupported leade distance**
- **Also occur when the center of mass is not in concentricity with the projectile and the bore**

(Right) Calculated x and y displacement of the center of the bourrelet of 3 different 155mm projectiles with a CG imbalance in a worn tube[1]

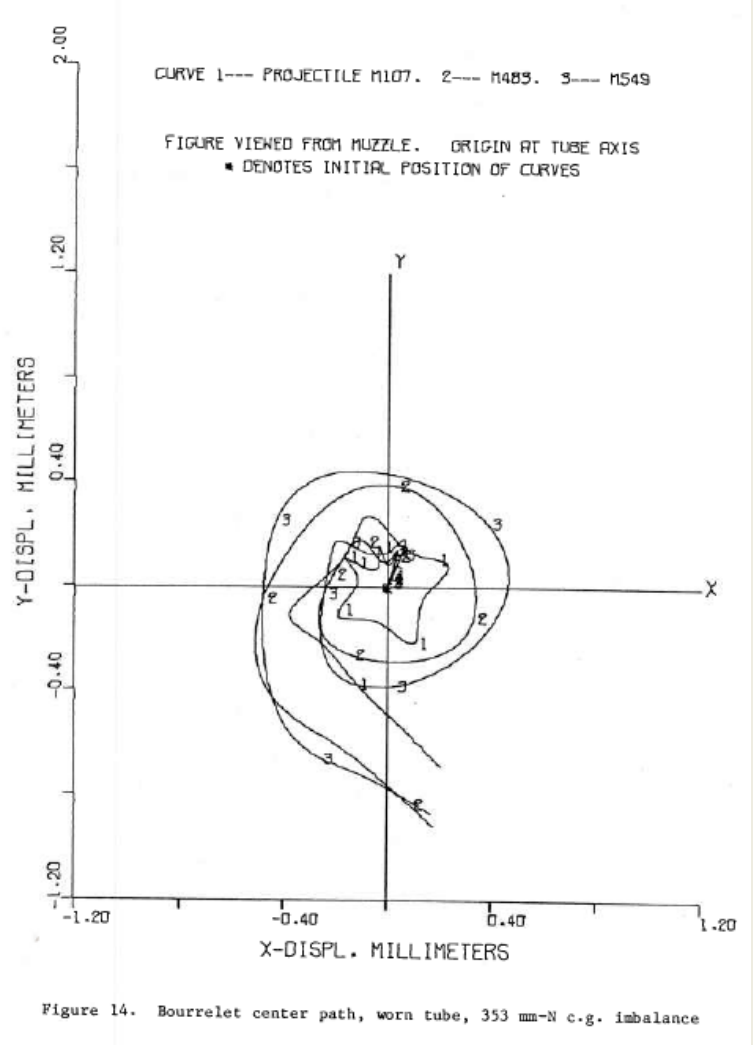


Figure 14. Bourrelet center path, worn tube, 353 mm-N c.g. imbalance

McCoy, R.L. "Modern Exterior Ballistics Second Edition," Atglen, PA. Schiffer. 2012
[1]Chu, S.H., "In-Bore Motion Analysis of 155mm Projectiles M107, M483A1, and M549 in M198 Gun," ARLCD-TR-80048, Large Caliber Weapon Systems Laboratory, Dover, NJ; October 1981

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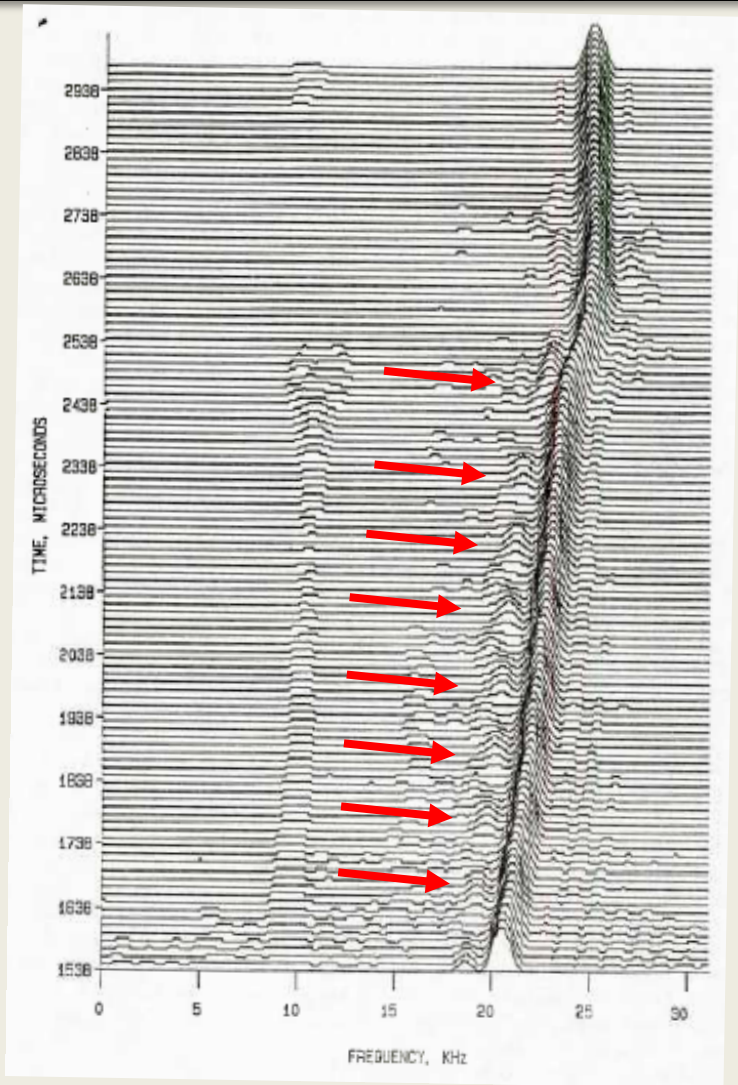
Large Caliber Techniques

ARL

- Analytical
  - Need for experimental data to inform modeling
- Optical Lever
  - Significant blow-by decreases signal
- In-bore Radar
  - Provides verification of balloting
  - Lacks detailed information
- On-board diagnostics
  - Small projectile size
  - High acceleration
  - Extremely harsh environment

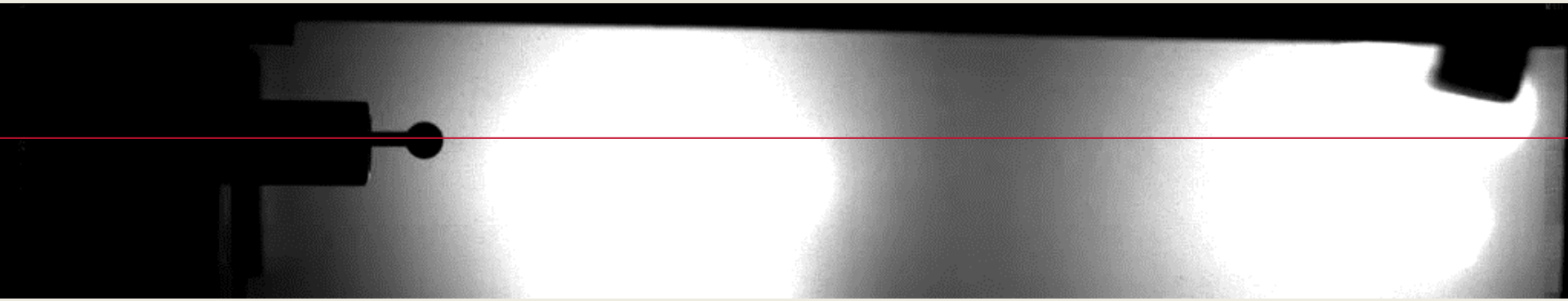


In-bore Radar technique showing balloting in a 37mm system[1]

[1]Haug, B.T., "Microwave Radar Techniques Applied to Gun Accuracy Measurements," BRL-MR-3581, Ballistics Research Laboratory, Aberdeen Proving Ground, Maryland; April 1987

Small Caliber Observations

- **Short gun experiments had noticeable off axis projectile movement**
  - **(Shown previously)**
- **Added a ‘flag’ to projectile for use in normal barrels**

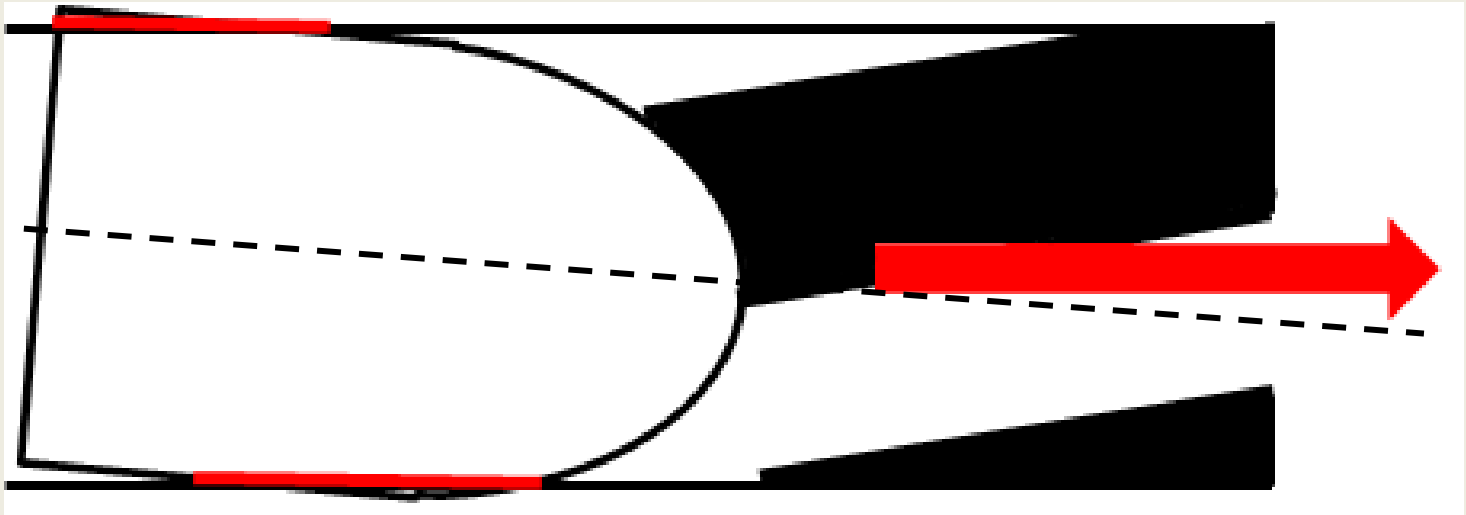


9mm, 5-in gun, 1:10 twist, 0.100” diameter carbon rod with flag

- **Flag and rod could be impacting the dynamics**
- **Rod noticeably bending and splitting after exiting the barrel**

Engraving Marks

- Grooves made on the projectile from the gun tube rifling
- Represent the entirety of balloting motion during launch
- Projectiles were caught using several feet of foam blocks
- Expectation:
  - Grooves mismatched fore and aft (location)
  - Variable groove length
  - Groove depth differences



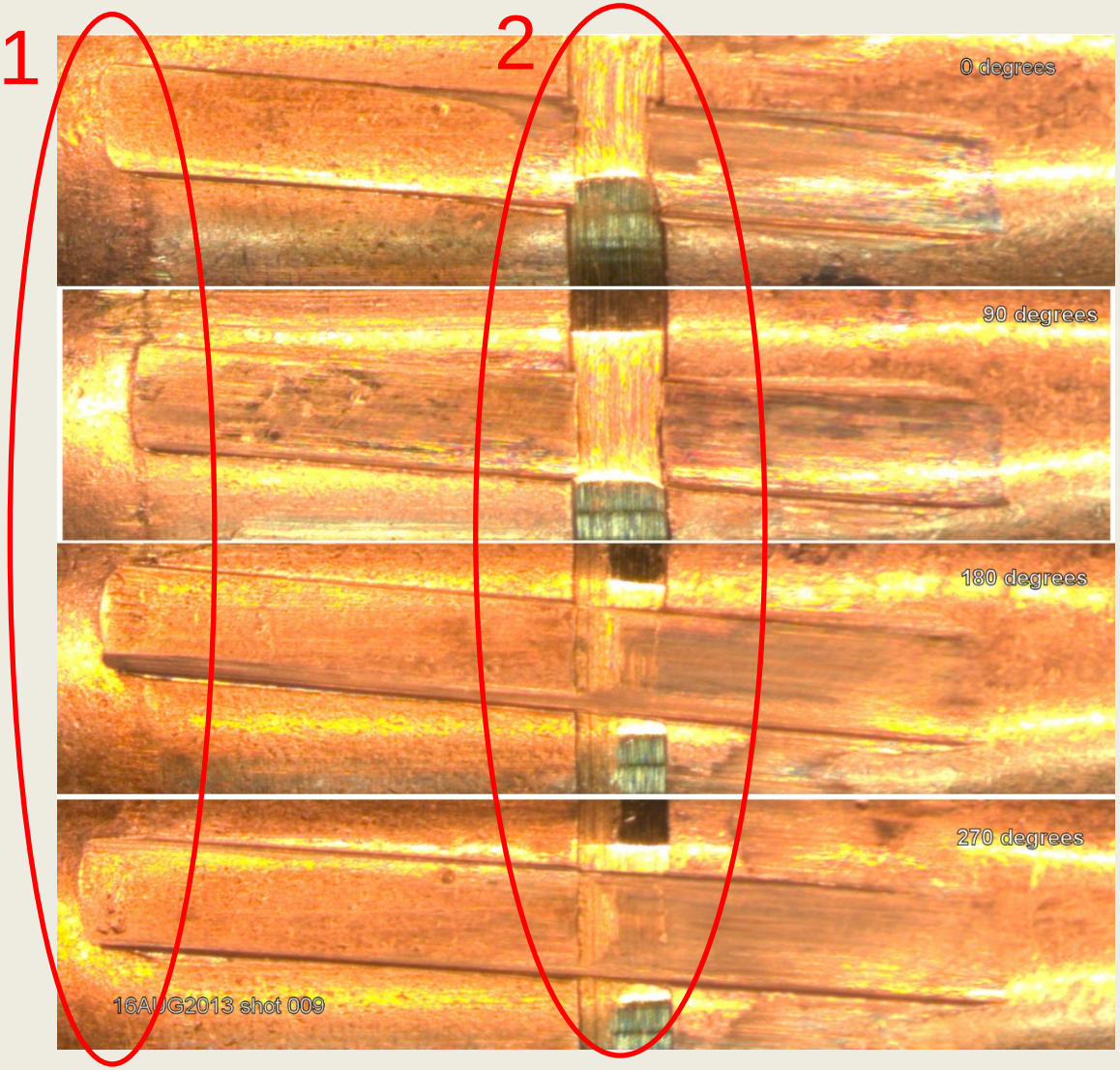
Projectile at 5° off axis (exaggeration). Note the different length markings and relative location

Engraving Marks (cont.)

- Recovered 7.62mm

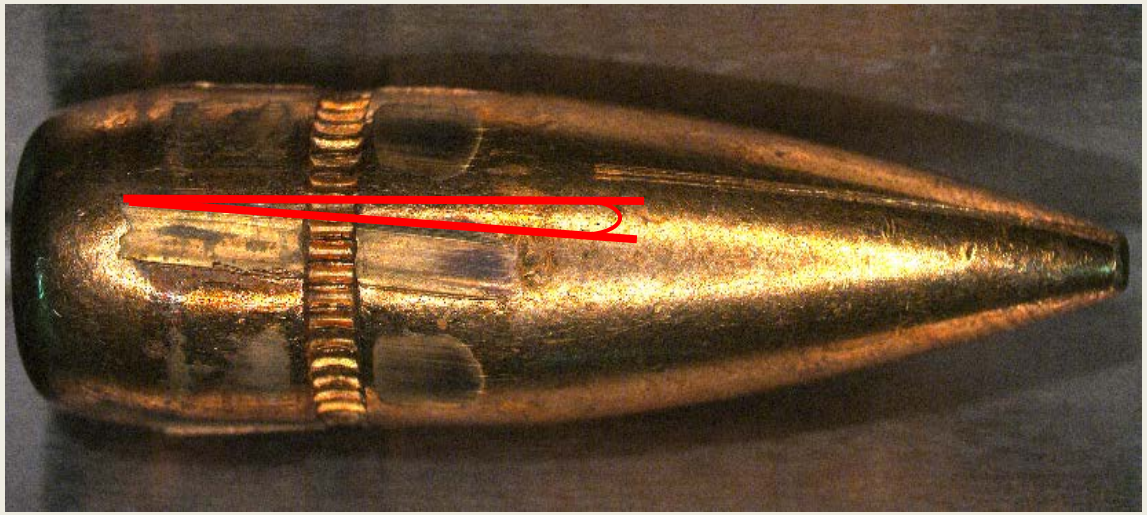
  1) Grooves mismatched location

  2) Groove depth differences



Engraving Marks (cont.)

- Groove angle also explored
- Difficult to make precise surface measurements due to cylindrical surface and no depth information



- Twist Angle = $\tan^{-1}(\pi d/n)$
- Where d is the projectile diameter and n is the twist rate (1 in n)

Engraving Marks (cont.)

- **Engraving marks on M80, 7.62mm, projectiles detailed in Table 1**
- **Very similar engraving angles around the projectile on both sides of the groove**
- **Engraved grooves approximately at the twist angle expected**

Table 1. Angle measurements of grooves cut into projectiles.

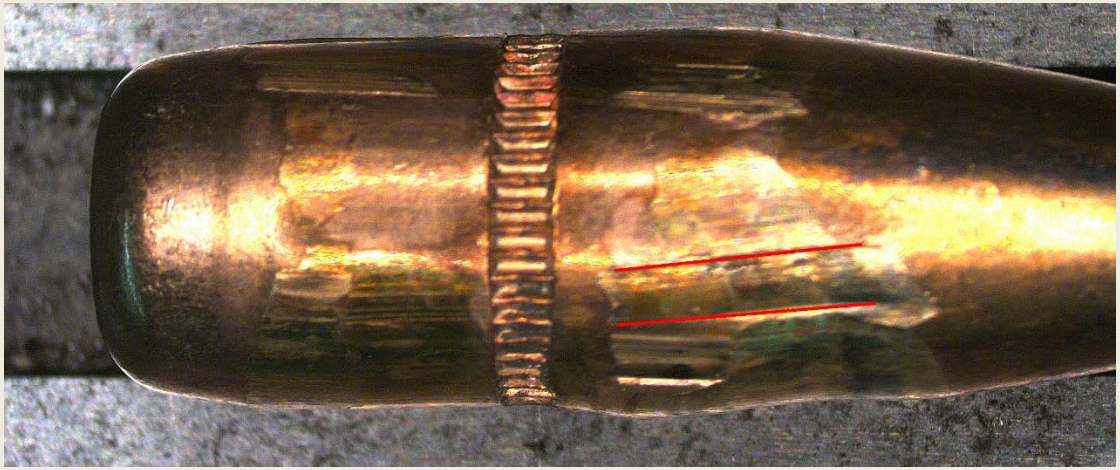
10-Inch Barrel Angles (degrees)				
Groove	Leading	Trailing	Leading	Trailing
1	5.36	5.23	0.12	0.17
2	5.38	5.21	0.15	0.22
3	5.43	5.13	0.21	0.07
4	5.42	5.22	0.11	0.19
	Averages		SD	
5-Inch Barrel Angles (degrees)				
Groove	Leading	Trailing	Leading	Trailing
1	5.23	5.05	0.12	0.08
2	5.30	5.10	0.27	0.46
3	5.43	4.91	0.09	0.31
4	5.21	5.05	0.09	0.15
	Averages		SD	

7.62mm with 1 in 10 twist
5.38°

Verification

- **Devise methods to induce exaggerated balloting and to validate the measurement process**
  - **Asymmetric CG projectile with base designed to promote non-axial engraving**
  - **Misaligned breech**
  - **Bent barrel to promote balloting**

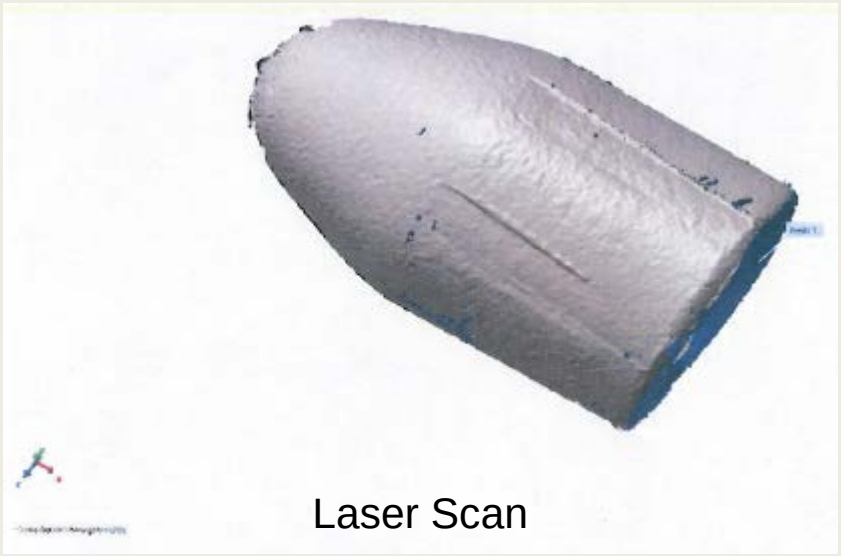
Chamfered 7.62mm with non axial CG



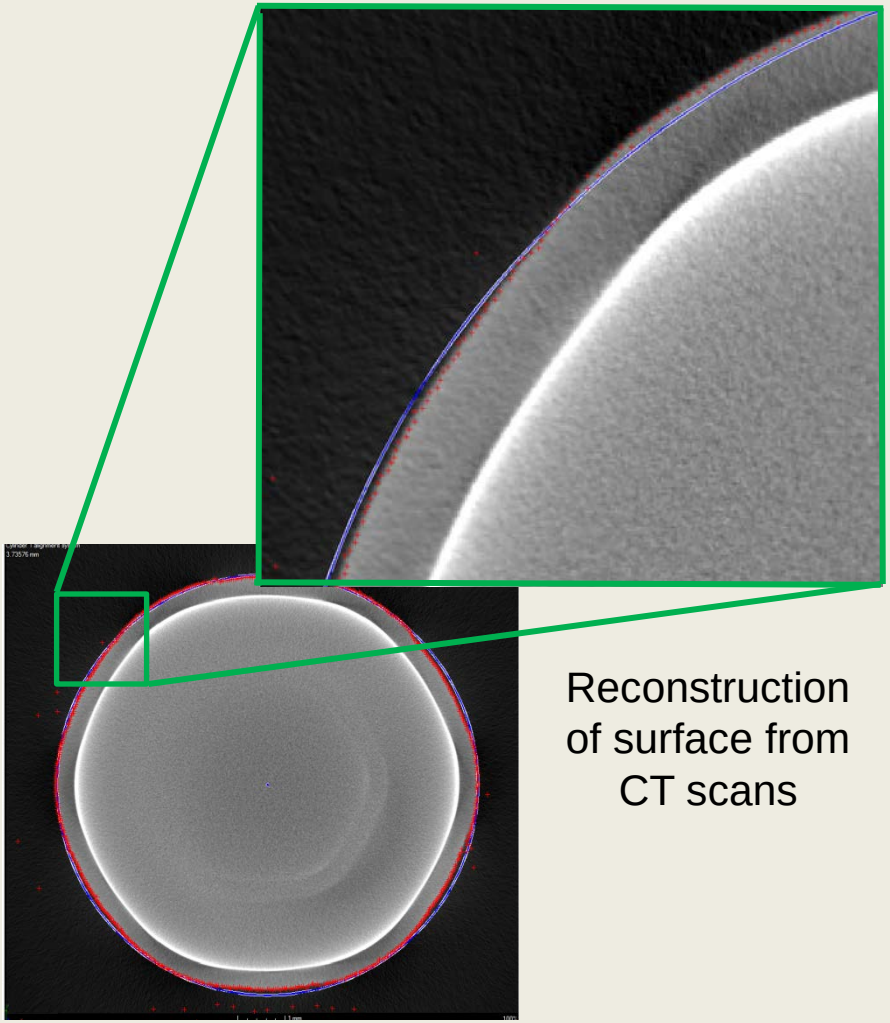
7.62mm Fired from barrel with 0.065” chamber offset

Current Work

- Exploring different options for measuring the engraving marks
- CT scan of the projectile and mapping the surface
- Blue light laser scanning
- These give more precise measurement of the location and depth of the engravings



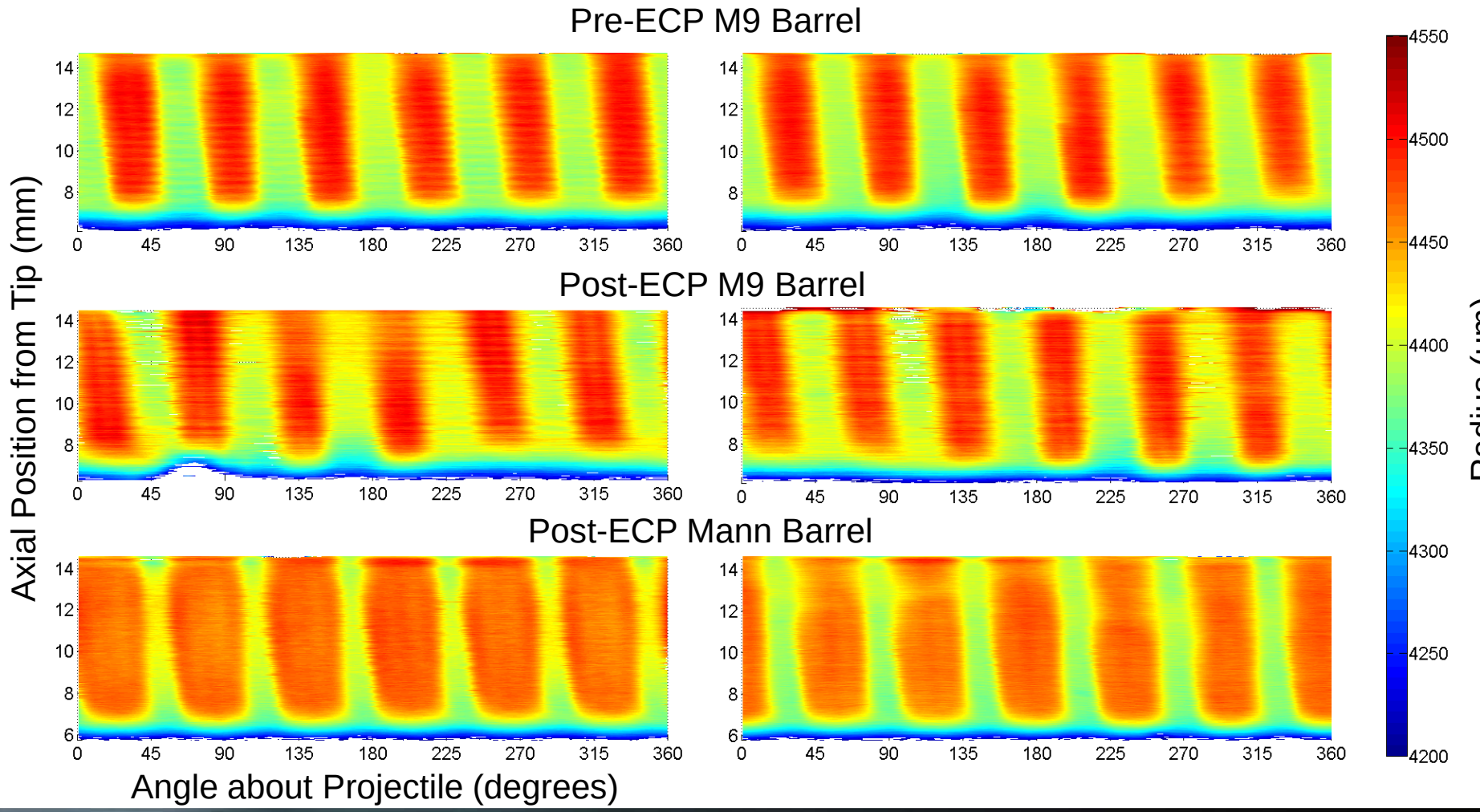
Laser Scan



Reconstruction of surface from CT scans

Current Work (cont.)

- 9mm CT scan surface maps
- Variation in engraving angle and location fore-aft



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